
DEVELOPMENT OF THE GEANT4 VALIDATION WEB INTERFACE FOR END USERS

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 - A. PDS Team
 - 1. Krzysztof Genser
 - 2. Tomasz Golan
 - 3. Robert Hatcher
 - 4. Adam Para
 - 5. Gabriel Perdue
 - 6. Hans-Joachim Wenzel
 - 7. Julia Yarba
- VIII. References

INTRODUCTION: GEANT4 BACKGROUND

- Models the interaction of particles with matter
- Wide breadth of scope
 - Education
 - Medicine
 - Space and Radiation
 - High Energy Physics
- Ever evolving

EVOLUTION AND IMPROVEMENT

- All aspects in scope of critical importance
- Constantly Improving
 - One major release per year
 - Several minor releases per year (average about 3)
- **Validation Library**
 - Keep track of improvements between releases
 - Data base which houses experimental and simulation data
 - Graphs stored as image blobs – becoming cumbersome
 - **Currently working to present data dynamically at the user's request**

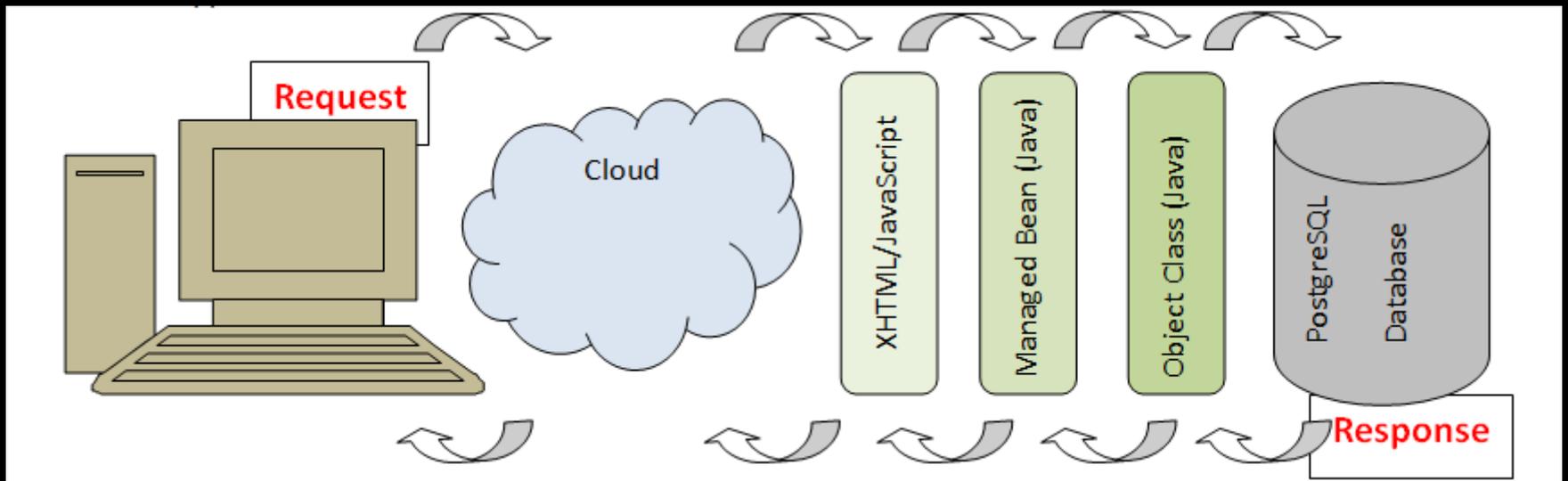
SOFTWARE TOOLS

- NetBeans 8.0 Integrated Development Environment (IDE)
 - Provides framework within which to edit, compile, and debug code
- PrimeFaces 4.0
 - Library providing rich, easily configurable user interface components
- JavaServer Faces (JSF) 2.0
 - Framework for constructing user interfaces with components
- PostgreSQL Database
 - Database within which the raw data and static images are stored

SOFTWARE TOOLS

- Java
 - Object oriented programming language with pre-defined classes and class objects
- JFreeChart
 - Chart viewing program which runs directly from Java
- JavaScript
 - Client side data parsing language compatible with web browsers
- HighCharts
 - JavaScript based chart viewing program
- XHTML
 - Webpage formatting language

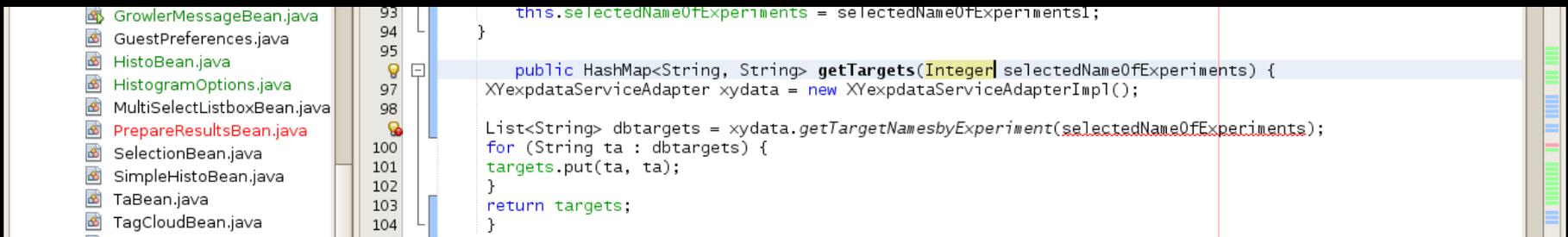
METHODS AT A GLANCE



PROGRAMMING METHODS

IDE

- All Programming, regardless of language, protocol, or tool kit was completed within the NetBeans 8.0 IDE.
 - Provides immediate feedback for coding discrepancies
 - Displays compiler read out to easily locate the position of compiler errors
 - Displays system read out statements for debugging
 - Capability to display project on built in browser or external browser.



```
93     this.selectedNameOfExperiments = selectedNameOfExperiments1;
94 }
95
96 public HashMap<String, String> getTargets(Integer selectedNameOfExperiments) {
97     XYexpdataServiceAdapter xydata = new XYexpdataServiceAdapterImpl();
98
99     List<String> dbtargets = xydata.getTargetNamesbyExperiment(selectedNameOfExperiments);
100     for (String ta : dbtargets) {
101         targets.put(ta, ta);
102     }
103     return targets;
104 }
```

PROGRAMMING METHODS

WEB PAGE

- XHTML main framework within which all other web page programming structured
- JavaScript used to parse data, complete actions, and fill HighCharts
- Heavy reliance on PrimeFaces 4.0 for easily configurable UI components
- JSF component library utilized where necessary

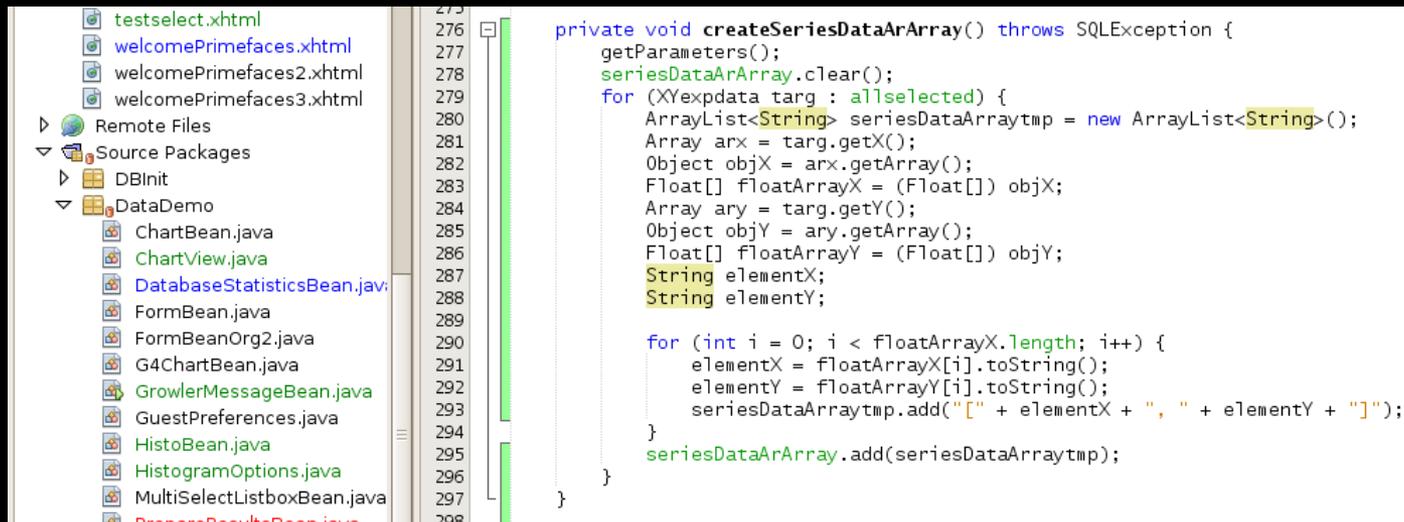


```
23 <script>
24     process = function()
25     {
26         window.open('about:blank', 'popup', 'width=320,height=400,resizeable=yes, scrollbars=yes');
27         document.login.setAttribute('target', 'popup');
28         document.login.setAttribute('onsubmit', '');
29         document.login.submit();
30     };
31 </script>
32 <f:facet name="first">
33     <meta content='text/html; charset=UTF-8' http-equiv="Content-Type"/>
34     <title>PrimeFaces</title>
35 </f:facet>
36 </h:head>
37
38 <h:body id="showdataForm">
39
40
41     <p:layout fullPage="true">
42
43         <p:layoutUnit position="north" size="120" resizable="true" closable="true" collapsible="true" >
44             
```

PROGRAMMING METHODS

MANAGED BEANS

- Managed Beans act as an intermediary to send request parameters to the Object Class and parse returned data into a usable format
- The data is then displayed presented on a JFreeCharts plot backed by a Java servlet and also passed back to the XHTML page



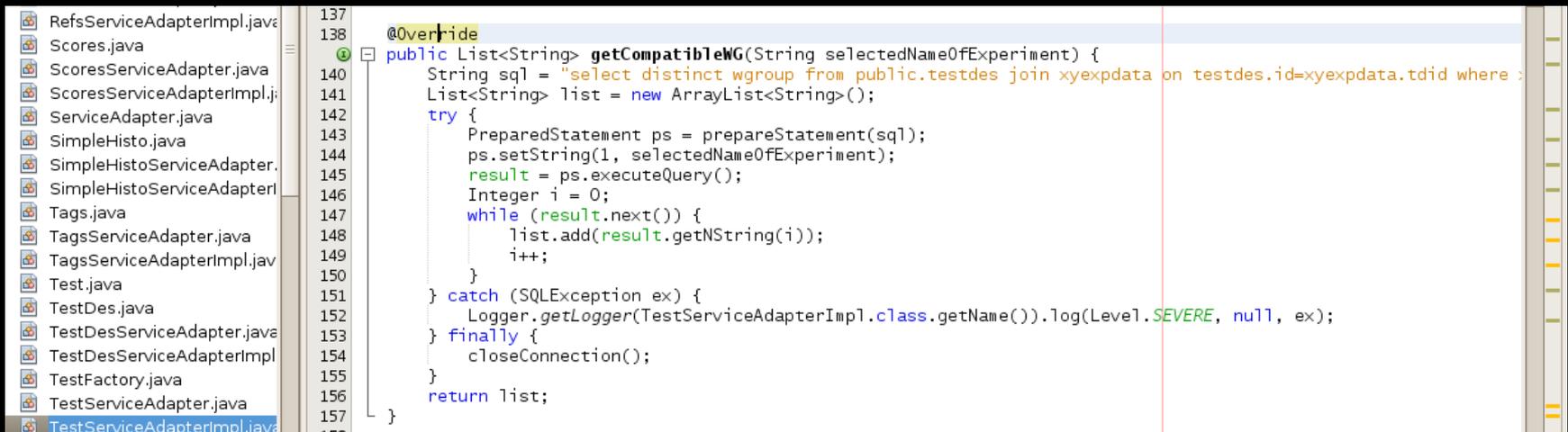
The screenshot shows an IDE with a project structure on the left and a code editor on the right. The project structure includes a 'DataDemo' package with several Java files, including 'ChartBean.java', 'ChartView.java', and 'DatabaseStatisticsBean.java'. The code editor displays the following Java code snippet:

```
275  
276  
277 private void createSeriesDataArArray() throws SQLException {  
278     getParameters();  
279     seriesDataArArray.clear();  
280     for (XYexpdata targ : allselected) {  
281         ArrayList<String> seriesDataAraytmp = new ArrayList<String>();  
282         Array arx = targ.getX();  
283         Object objX = arx.getArray();  
284         Float[] floatArrayX = (Float[]) objX;  
285         Array ary = targ.getY();  
286         Object objY = ary.getArray();  
287         Float[] floatArrayY = (Float[]) objY;  
288         String elementX;  
289         String elementY;  
290  
291         for (int i = 0; i < floatArrayX.length; i++) {  
292             elementX = floatArrayX[i].toString();  
293             elementY = floatArrayY[i].toString();  
294             seriesDataAraytmp.add "[" + elementX + ", " + elementY + "];");  
295         }  
296         seriesDataArArray.add(seriesDataAraytmp);  
297     }  
298 }
```

PROGRAMMING METHODS

OBJECT CLASS

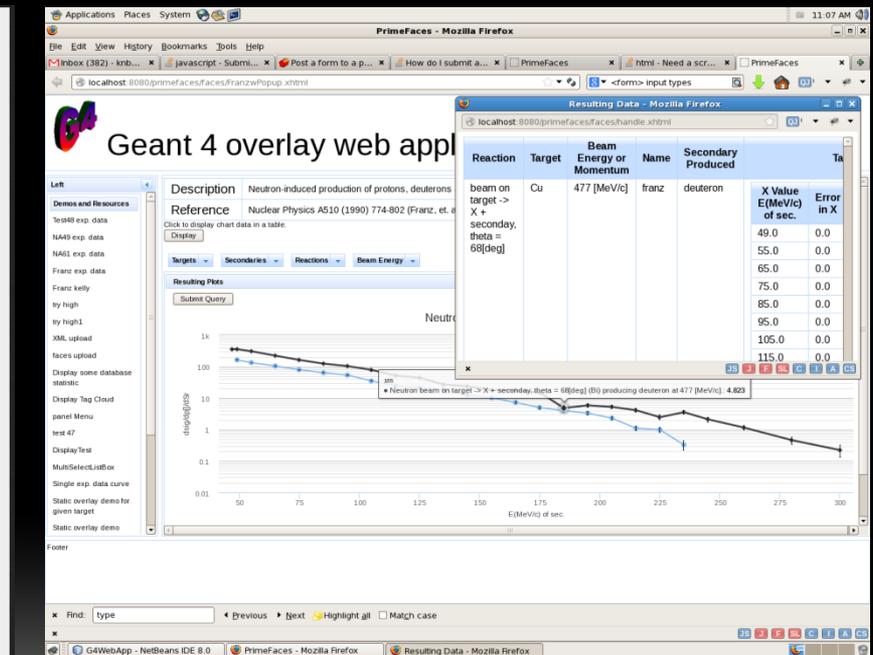
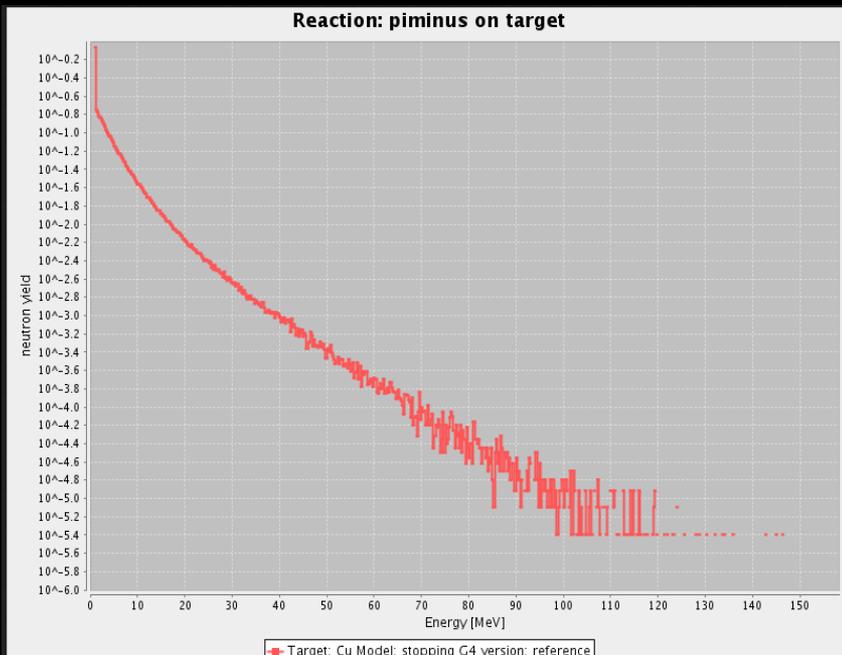
- Object classes define non-Java items in such a way that Java can manipulate them.
- They receive parameter values from the managed bean; typically a string or integer.
- These values are placed into a prepared SQL statement which the object class passes to the database.
- They then iterate over the database responses and define them for further parsing before passing them back to the managed bean.



```
137
138
139 @Override
140 public List<String> getCompatibleWG(String selectedNameOfExperiment) {
141     String sql = "select distinct wgroup from public.testdes join xyexpdata on testdes.id=xyexpdata.tdid where ";
142     List<String> list = new ArrayList<String>();
143     try {
144         PreparedStatement ps = prepareStatement(sql);
145         ps.setString(1, selectedNameOfExperiment);
146         result = ps.executeQuery();
147         Integer i = 0;
148         while (result.next()) {
149             list.add(result.getString(i));
150             i++;
151         }
152     } catch (SQLException ex) {
153         Logger.getLogger(TestServiceAdapterImpl.class.getName()).log(Level.SEVERE, null, ex);
154     } finally {
155         closeConnection();
156     }
157     return list;
158 }
```

RESULTS

- Each individual, complete method functions as intended; however, they are not yet assembled into one coherent web application.



RESULTS: DATABASE STATISTICS

The screenshot shows a Mozilla Firefox browser window displaying the 'Geant 4 database statistics' page. The page features a navigation menu on the left and a main content area with four tables and two pie charts.

Geant 4 database statistics

Test Setups	Test Results (all)	Public Tests	Internal Tests
21	18414	6103	12081

Types of Public Tests		Number of Each Type
electromagnetic		18
hadronic		6067
LHC-feedback		18

Types of Internal Tests		Number of Each Type
electromagnetic		274
hadronic		11807
LHC-feedback		0

Two pie charts illustrate the distribution of test types. The top chart, labeled 'Public Tests', shows 99% hadronic tests. The bottom chart, labeled 'Internal Tests', shows 98% hadronic tests. Both charts include a legend with categories: electromagnetic (blue), hadronic (orange), and LHC-feedback (yellow).

Footer

RESULTS: TOP SELECTION

Applications Places System 9:38 PM

PrimeFaces - Mozilla Firefox

File Edit View History Bookmarks Tools Help

PrimeFaces

localhost:8080/primefaces/faces/testselect.xhtml

Google

Geant 4 overlay web application demo

Left

- franz
- Madey et al.
- NA61
- NA49

Submit

Demos and Resources

- Test48 exp. data
- NA49 exp. data
- NA61 exp. data
- Franz exp. data
- Franz kelly
- try high
- try high1
- XML upload
- faces upload
- Display some database statistic
- Display Tag Cloud
- panel Menu
- test 47
- DisplayTest
- MultiSelectListBox
- Single exp. data curve
- Static overlay demo for given target
- Static overlay demo
- Pie Demo
- Primefaces Demo

Footer

G4WebApp - NetBeans IDE 8.0 PrimeFaces - Mozilla Firefox

RESULTS: REFINE BY TARGET

Applications Places System 9:38 PM

PrimeFaces - Mozilla Firefox

File Edit View History Bookmarks Tools Help

PrimeFaces

localhost:8080/primefaces/faces/FranzwPopup.xhtml

Google

Geant 4 overlay web application demo

Left

Demos and Resources

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- Static overlay demo
- Pie Demo
- Primefaces Demo

Description Neutron-induced production of protons, deuterons and tritons in Copper and Bismuth.

Reference Nuclear Physics A510 (1990) 774-802 (Franz, et. al.)

Click to display chart data in a table.

Display

Targets Secondarys Reactions Beam Energy

Cu Pb C Al Ta N O

Neutron Ind

Footer

G4WebApp - NetBeans IDE 8.0 PrimeFaces - Mozilla Firefox

RESULTS: REFINE BY SECONDARY

Applications Places System 9:38 PM

PrimeFaces - Mozilla Firefox

File Edit View History Bookmarks Tools Help

PrimeFaces

localhost:8080/primefaces/faces/FranzwPopUp.xhtml

Google

Geant 4 overlay web application demo

Left

- Demos and Resources
- Test48 exp. data
- NA49 exp. data
- NA61 exp. data
- Franz exp. data
- Franz kelly
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Description Neutron-induced production of protons, deuterons and tritons in Copper and Bismuth.

Reference Nuclear Physics A510 (1990) 774-802 (Franz, et. al.)

Click to display chart data in a table.

Targets **Secondaries** **Reactions** **Beam Energy**

Resulting Plot

Submit Query neutron

Footer

G4WebApp - NetBeans IDE 8.0 PrimeFaces - Mozilla Firefox

RESULTS: REFINE BY REACTION

The screenshot shows a web browser window titled "PrimeFaces - Mozilla Firefox" displaying a web application. The application title is "Geant 4 overlay web application demo". The main content area is titled "Neutron-Induced Particle Production". It features a search and filter interface with the following elements:

- Description:** Neutron-induced production of protons, deuterons and tritons in Copper and Bismuth.
- Reference:** Nuclear Physics A510 (1990) 774-802 (Franz, et. al.)
- Filtering Options:** Three dropdown menus labeled "Targets", "Secondaries", and "Beam Energy".
- Search Input:** A text input field with a search icon and a close button (X).
- Resulting Plots:** A section containing a checkbox and the text "piminus on target".
- Submit Query:** A button to execute the search.

A sidebar on the left lists "Demos and Resources" including various data files and application features. The bottom of the browser window shows the taskbar with "G4WebApp - NetBeans IDE 8.0" and "PrimeFaces - Mozilla Firefox" open.

RESULTS: REFINE BY BEAM ENERGY

The image shows a screenshot of a web browser displaying a web application titled "Geant 4 overlay web application demo". The browser's address bar shows the URL "localhost:8080/primefaces/faces/FranzwPopup.xhtml". The application interface includes a left sidebar with a "Demos and Resources" menu, a main content area with a "Description" and "Reference" section, and a "Beam Energy" dropdown menu. The dropdown menu is open, showing two options: "1.4 [GeV/c]". A larger, semi-transparent inset window highlights the "Beam Energy" dropdown menu and its options.

Applications Places System 9:38 PM

PrimeFaces - Mozilla Firefox

File Edit View History Bookmarks Tools Help

PrimeFaces

localhost:8080/primefaces/faces/FranzwPopup.xhtml

Google

G4 Geant 4 overlay web application demo

Left

Demos and Resources

- Test48 exp. data
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- Pie Demo
- Primefaces Demo

Description Neutron-induced production of protons, deuterons and tritons in Copper and Bismuth.

Reference Nuclear Physics A510 (1990) 774-802 (Franz, et. al.)

Click to display chart data in a table.
Display

Targets Secondary Reactions Beam Energy

Resulting Plots

Submit Query

Beam Energy

- 1.4 [GeV/c]
- 1.4 [GeV/c]

Footer

G4WebApp - NetBeans IDE 8.0 PrimeFaces - Mozilla Firefox

RESULTS: DYNAMICALLY CREATED PLOT

Applications Places System 11:07 AM

PrimeFaces - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Inbox (382) - knb... javascript - Submi... Post a form to a p... How do I submit a... PrimeFaces html - Need a scr... PrimeFaces

localhost:8080/primefaces/faces/FranzwPopup.xhtml

G4 Geant 4 overlay web app

Left

Demos and Resources

- Test48 exp. data
- NA49 exp. data
- NA61 exp. data
- Franz exp. data
- Franz kelly
- try high
- try high1
- XML upload
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- Display some database statistic
- Display Tag Cloud
- panel Menu
- test 47
- DisplayTest
- MultiSelectListBox
- Single exp. data curve
- Static overlay demo for given target
- Static overlay demo

Description: Neutron-induced production of protons, deuterons

Reference: Nuclear Physics A510 (1990) 774-802 (Franz, et. al.)

Click to display chart data in a table.
Display

Targets Secondaries Reactions Beam Energy

Resulting Plots

Submit Query

Neutron beam on target -> X + secondary, theta = 68[deg] (Bi) producing deuteron at 477 [MeV/c]: 4.823

Reaction	Target	Beam Energy or Momentum	Name	Secondary Produced	X Value E(MeV/c) of sec.	Error in X
beam on target -> X + secondary, theta = 68[deg]	Cu	477 [MeV/c]	franz	deuteron	49.0	0.0
					55.0	0.0
					65.0	0.0
					75.0	0.0
					85.0	0.0
					95.0	0.0
					105.0	0.0
					115.0	0.0

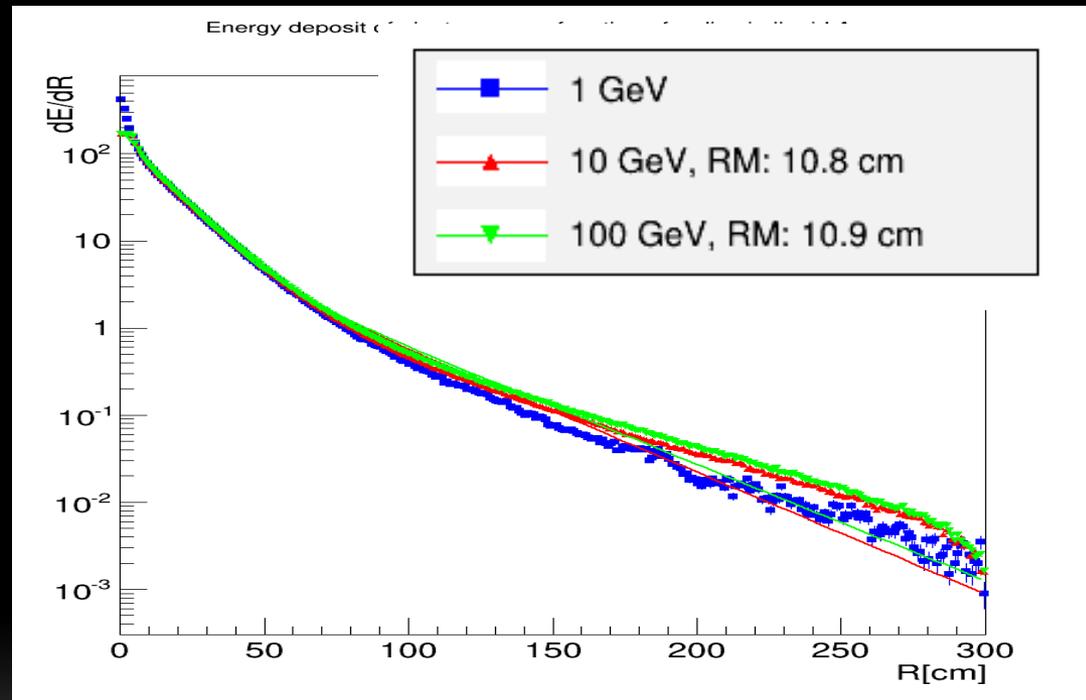
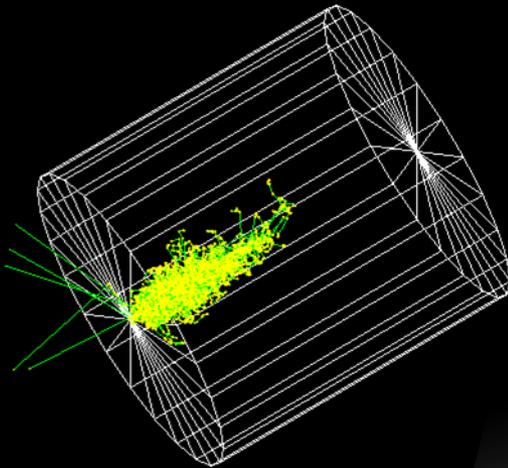
JS J F SL C I A CS

Find: type Previous Next Highlight all Match case

G4WebApp - NetBeans IDE 8.0 PrimeFaces - Mozilla Firefox Resulting Data - Mozilla Firefox

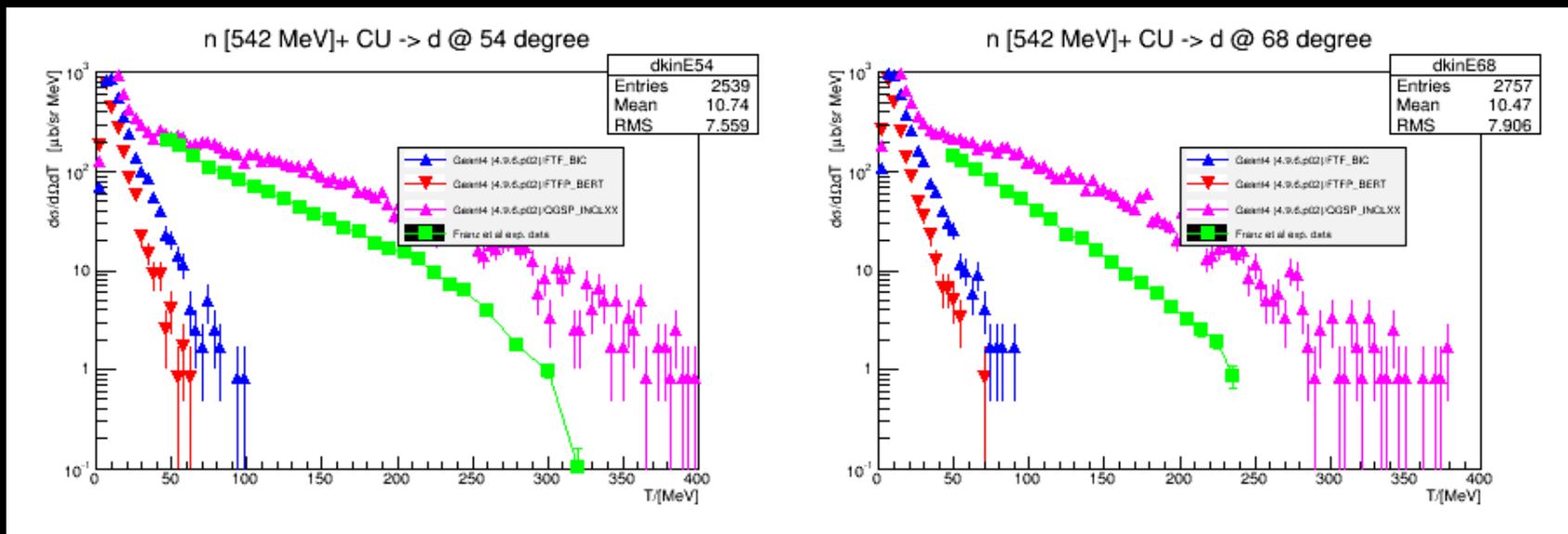
DISCUSSION: GEANT4 VALIDATION

- Precise liquid argon modeling crucial due to use in future experiments
 - LArIAT
 - MicroBoone
 - LBNE



DISCUSSION: GEANT4 VALIDATION

- Geant4 is the current standard for modelling physical interaction, and popularity is growing.
- As the user base increases, so must ease of use as well as number of tests.



CONCLUSION

- Discussed
 - What Geant4 is and its implications
 - Current application being created
 - Materials and Methods
 - Results and Discussion
- Continuous validation is key to improvement
- Expanding the validation library is the only means by which to do that
- A more diverse, robust validation library from which to draw upon will attract a wider audience

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- PDS Team:
 - Krzysztof Genser
 - Tomasz Golan
 - Robert Hatcher
 - Adam Para
 - Gabriel Perdue
 - Hans-Joachim Wenzel
 - Julia Yarba

REFERENCES

- [1] K. Kleinknecht, "Measurement of ionization," in Detectors for Particle Radiation, 2nd ed. Cambridge: CU Press, 1998, ch. 2, sec. 4, pp. 59.
- [2] H. Schultz-Coulon, "Calorimetry I: Electromagnetic Calorimeters," Univ. Heidelberg, Heidelberg, DE, Rep. 2014.
- [3] Atlas (2007). Liquid argon properties [Online]. Available: http://lartpc-docdb.fnal.gov/cgi-bin/RetrieveFile?docid=206;filename=Liquid_argon_properties.pdf;version=1

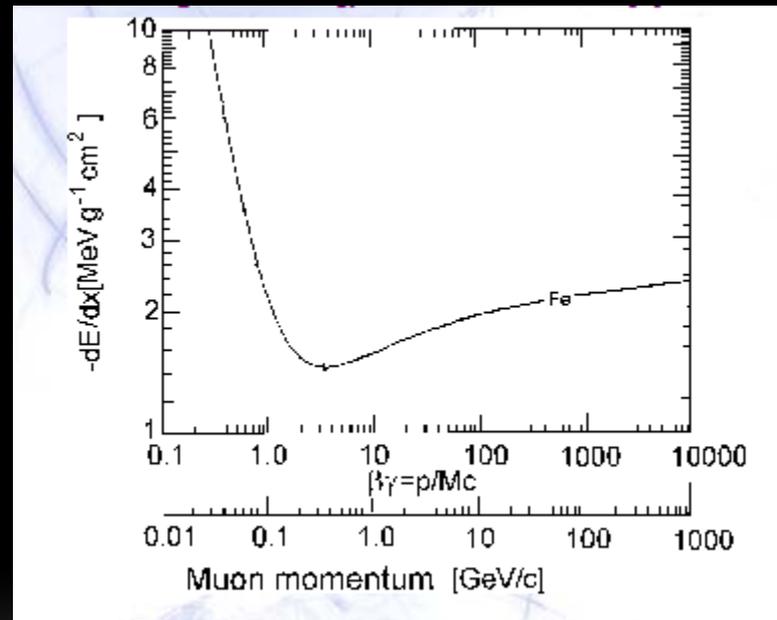
APPENDIX: SUPPLEMENTAL MATERIAL

EXAMPLE IN MEDICINE: PROTON THERAPY

- Bethe-Bloch equation describes the stopping power as a function of the change in energy of the beam per change in distance and

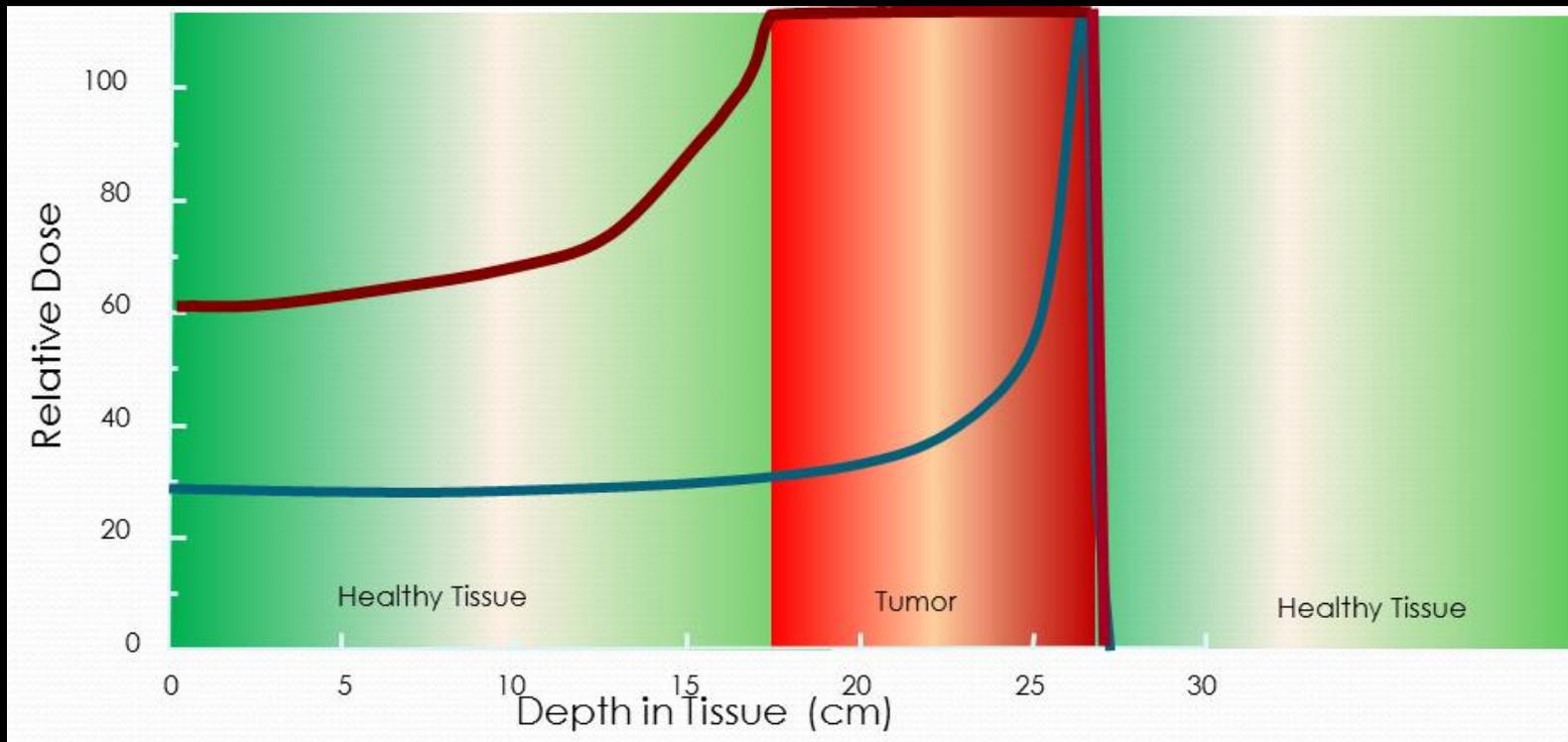
- $$-\frac{dE}{dx} = K Z^2 \frac{Z}{A} \frac{1}{\beta^2} \left[\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 T_{max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2} \right]$$

- $$K \equiv 4\pi N_A r_e^2 m_e c^2 / A$$



EXAMPLE IN MEDICINE: PROTON THERAPY

- A Bragg Peak is the point at which an element loses momentum and deposits most of its energy.
- By varying the beam intensity over time, the Bragg Peak can be spread out.

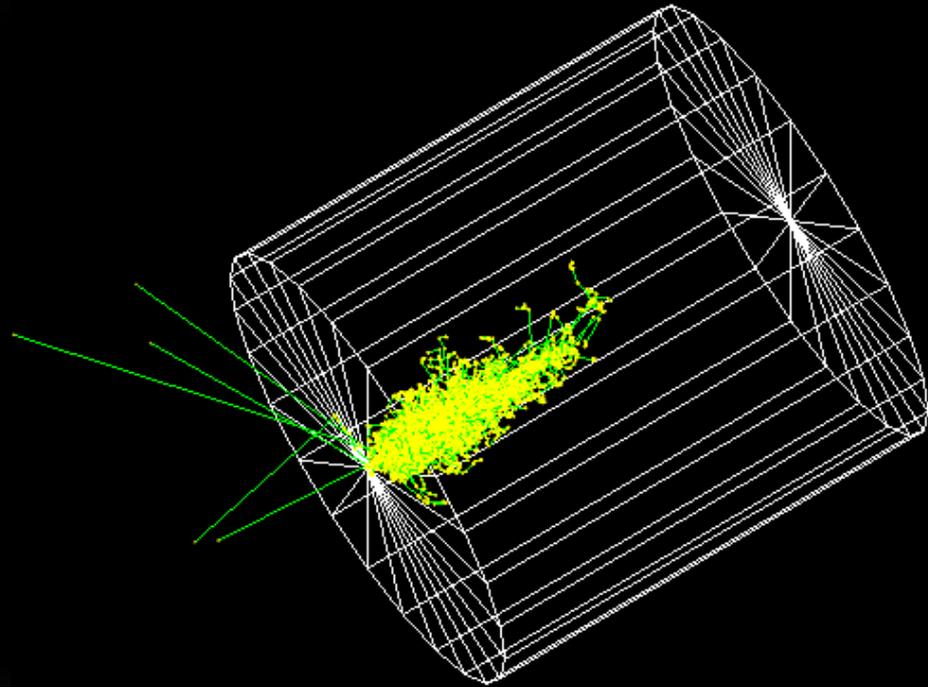


LIQUID ARGON

Property	Value
ρ (density)	1.4 g/cm^3
R_M (Moliere Radius)	9 – 11 cm
X_0 (Radiation Length)	14 cm
Z (Atomic Number)	18
A (Atomic Weight)	39.94
IA (Nuclear Interaction Length)	83.6 cm

GEANT4 SIMULATION OF EM SHOWER IN LIQUID ARGON

- 10 GeV Beam
- Liquid Argon Target
 - Radius: 3 m
 - Length: 6 m

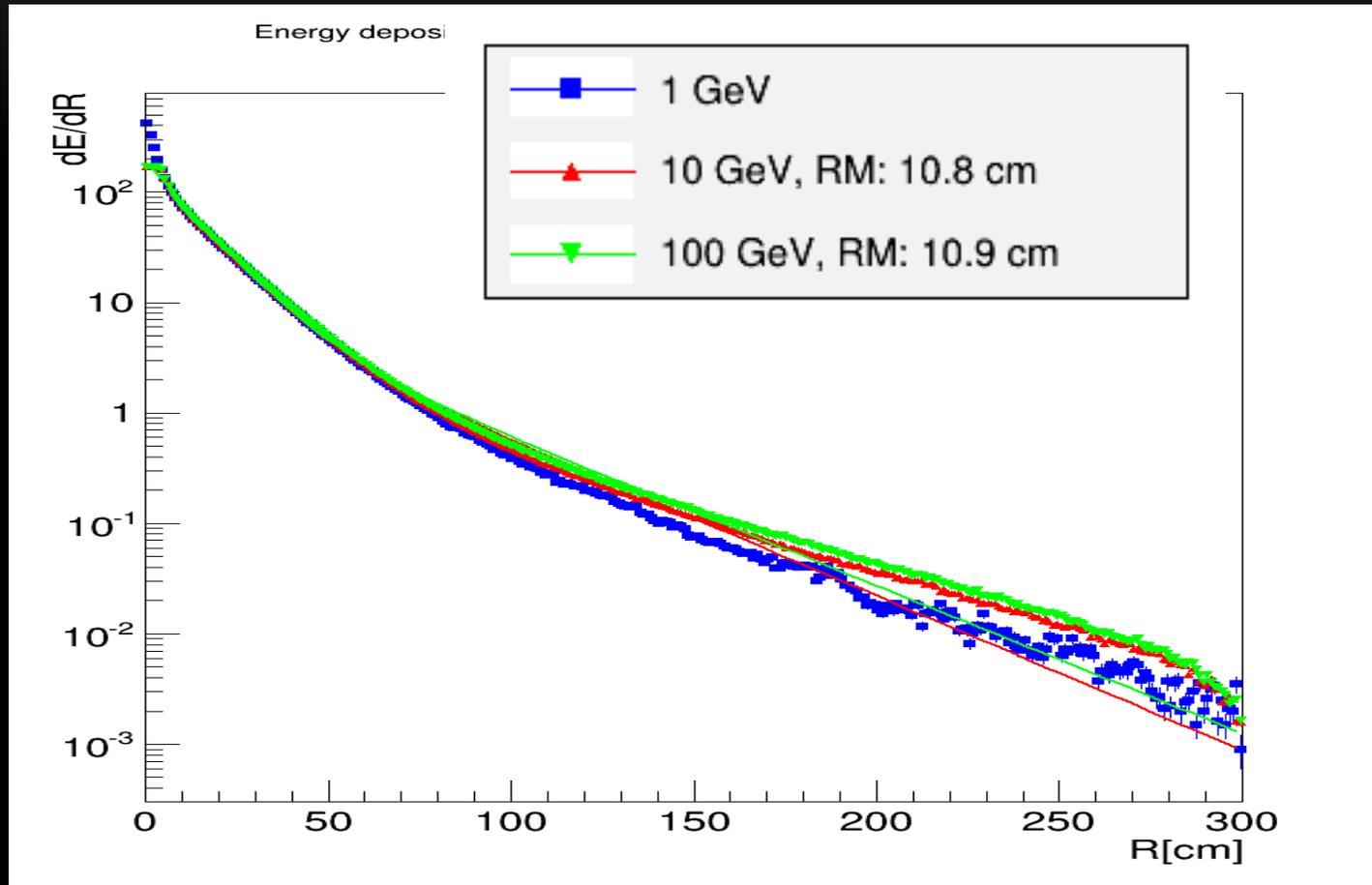


TRANSVERSE ELECTROMAGNETIC SHOWER PROFILE

- Radius within which 90% of the interactions occur
 - Literature: 9-11 cm [1]
 - Geant4: 11.31 cm
- $F(z) = \alpha e^{-\frac{R}{R_M}} + \beta e^{-\frac{R}{\lambda_{min}}}$ [2]
 - $\alpha \equiv$ short depth parameter
 - Dominates within the Moliere Radius
 - $\beta \equiv$ long depth parameter
 - Dominates beyond the Moliere Radius
 - It is important to note the parameters of the double exponential formula are highly correlated, so one must carefully interpret the 11.32 cm.

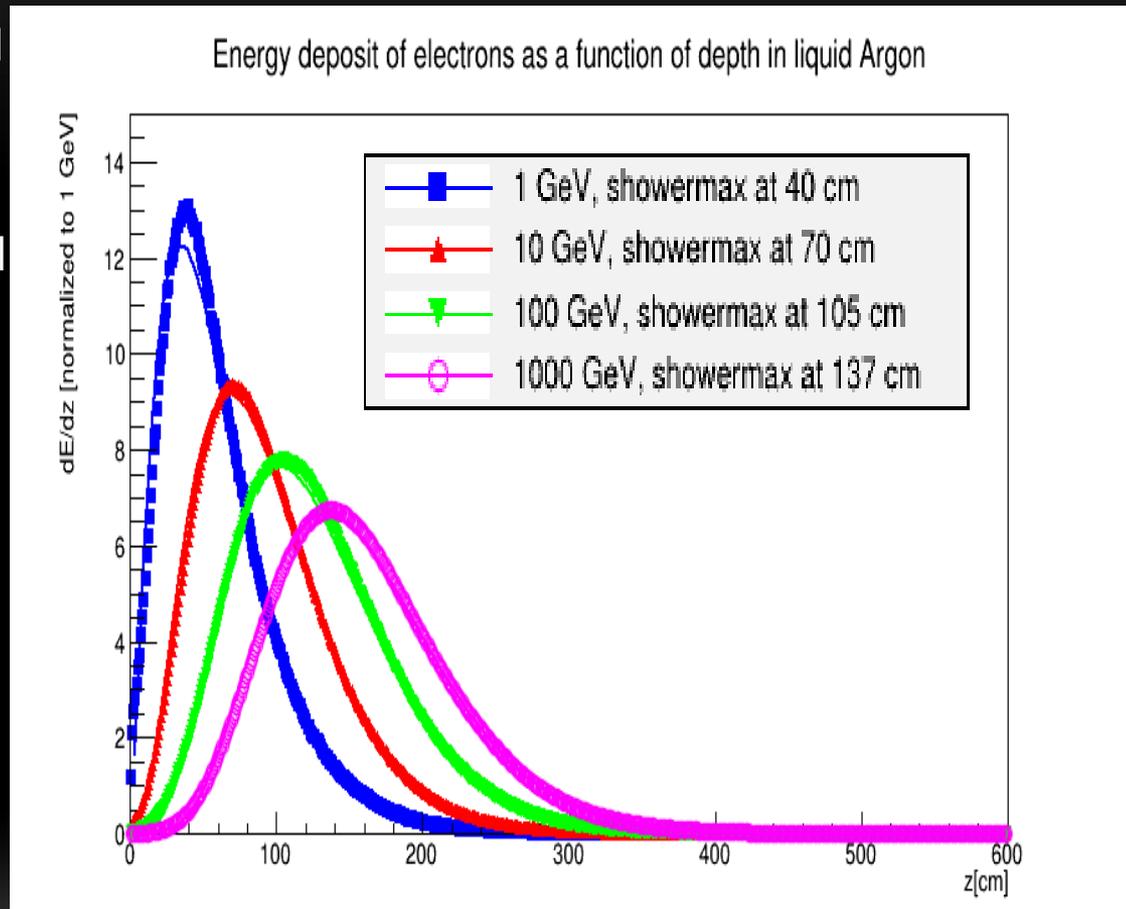
TRANSVERSE ELECTROMAGNETIC SHOWER PROFILER RADIUS (M_R)

- Primarily energy independent except at tails ends

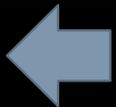


LONGITUDINAL PROFILE

- $\frac{dE}{dt} = E_0 \left(\frac{z}{X_0}\right)^\alpha e^{-\beta\left(\frac{z}{X_0}\right)}$ [2]
- Radiation length (X_0)
 - Characterizes the material
 - When used as a unit of measure, produces the same curve regardless of the target material
- Fit for X_0
 - 12 (10 GeV)
 - 13.7 (100 GeV)
 - 14.6 (1000 GeV)



SHOWER MAX (T_{MAX})

- Depth at which the maximum energy is deposited.
- $t_{max} = \ln \frac{E_0}{E_c} - 1$ [2]  (Rule of thumb)
- By nature, “rule of thumb” is imprecise

Peak Energy (GeV)	1	10	100	1000
Manual Calculation (cm)	33	65	97.4	129.6
G4 (cm)	40	70	105	137

SHOWER MAX (T_{MAX})

Ln ($E0/Ec$) vs. Shower Max [cm] for Simulation and Rule of Thumb Calculation

